PROGRAMMED INSTRUCTION

Magnetic Theory

MAGNETISM

P-IV-1R

Naval Air Technical Training Command

CNATT-M544 PAT

OBJECTIVES

P-IV-1R--Magnetic Theory: Magnetism

The student will:

1. Select a statement that defines magnetism. (1)
2. Select statements that correctly describe the properties of a magnetic field. (2-7)
3. List two types of artificial magnets. (10)
4. Select a statement that correctly defines a domain. (13-17)
5. Match each of the following terms with the correct definition: (21)

   a. flux density,
   b. reluctance,
   c. permeance, and
   d. retentivity.

6. State the definition of residual magnetism. (24)
7. State the definition of magnetizing force (H). (24)
8. State the definition of reluctivity (ν). (24)
9. Select the definition of permeability (μ). (24)

SUGGESTED READING TIME 48 MINUTES

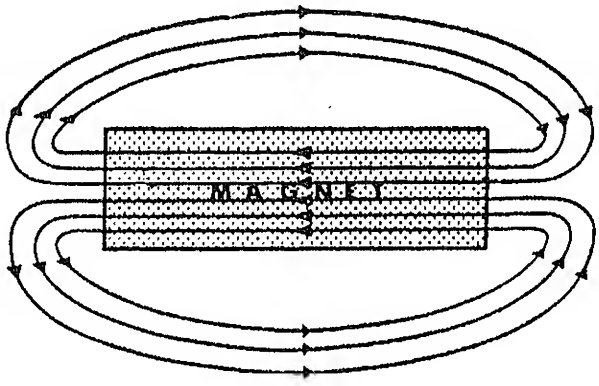
NOTE: The system of measurement used in this program is the CGS (centimeter-gram-second) system.

1. Magnetism is an invisible force that has the ability to attract or repel certain materials. These materials (such as iron, steel, cobalt, and nickel) must have special magnetic qualities in order for this invisible force (magnetism) to affect them.

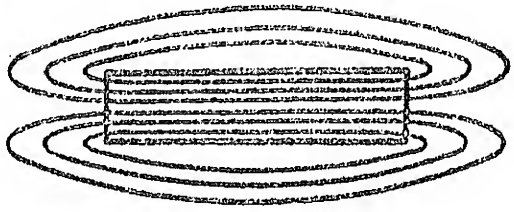
   Magnetism is an invisible force that has the ability to _____ or _____ certain materials.

attract
repel

2. The area around a magnetic material in which the invisible force magnetism can be detected is known as a magnetic field. The magnetic field has certain properties and characteristics; and in order to make the understanding of these properties easier, the magnetic field, which is a uniform force field, is considered to be distinct lines. See the figure below.



2. (Continued)

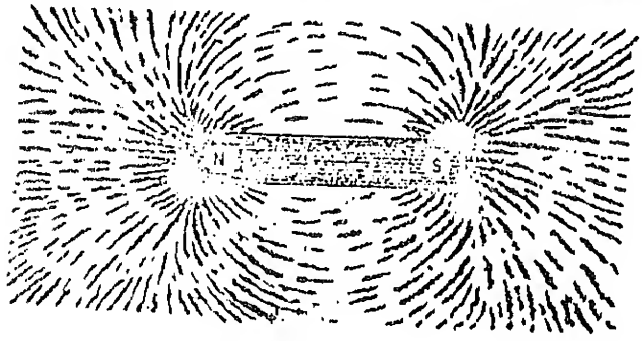


Magnetic lines of force (flux) always exist in closed loops and are always complete, as shown in the figure above.

Magnetic lines of force always form _____

_____

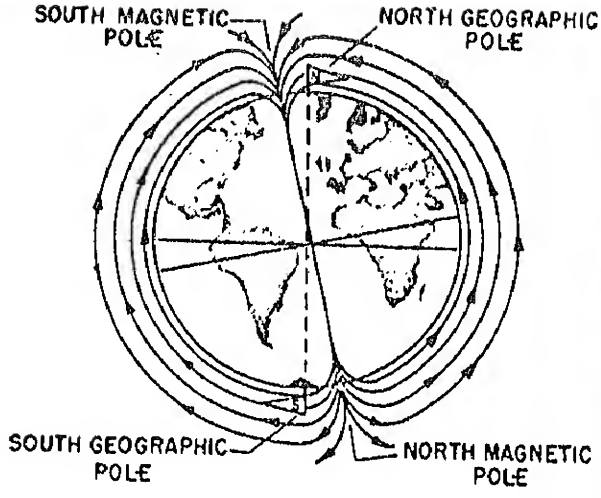
3.



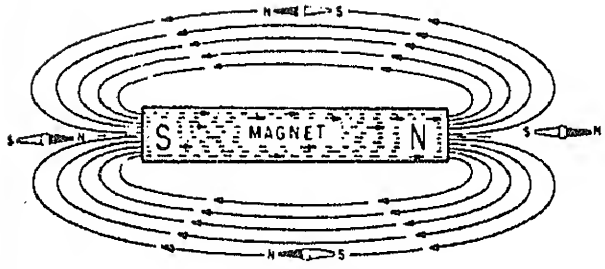
If iron filings are sprinkled in the magnetic field, most of the filings will be attracted and will collect in a definite pattern around the magnet (see the figure above). This pattern is caused by an invisible magnetic field, called magnetic force, that surrounds all magnets.

Magnetic force is concentrated at the poles of a magnet.

3. (Continued)



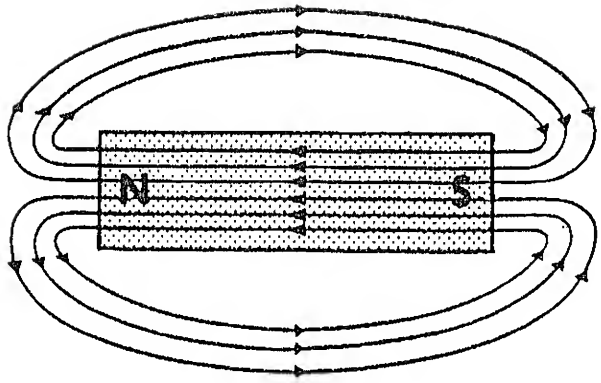
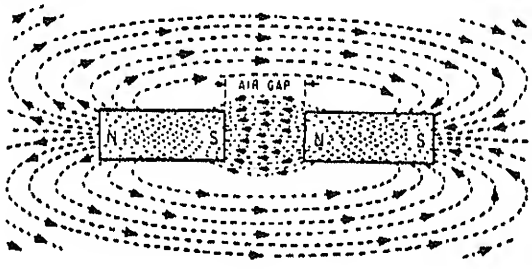
EARTH'S MAGNETIC POLES.

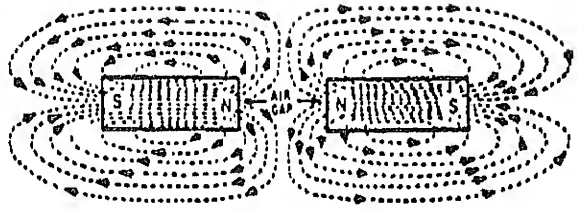
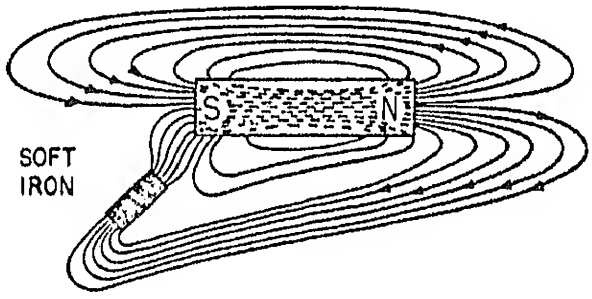


BAR MAGNET.

The poles of a magnet are the ends where most of the magnetic force is concentrated. All magnets have a north pole and a south pole. The magnetic strength of the north pole and the magnetic strength of the south pole of the same magnet are equal.

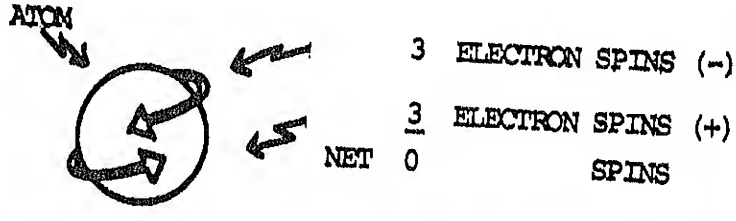
Magnetic force is concentrated at the _____ of a magnetic.

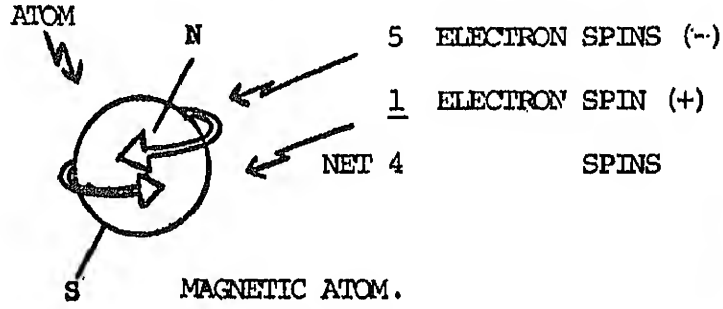
poles	4.  Magnetic lines of force (flux) are directional. Outside a magnet, the magnetic flux lines always leave the north pole and enter the south pole. Inside a magnet, the magnetic flux lines flow from the south pole to the north pole, as shown in the figure above. The direction of magnetic lines of force outside a magnet is from the _____ pole to the _____ pole.
north south	5.  UNLIKE POLES ATTRACT Figure 5-1

	5. (Continued)  LIKE POLES REPEL Figure 5-2 The basic law of magnetism states that like poles repel and unlike poles attract. See figure 5-1 and figure 5-2. Like poles _____. Unlike poles _____.
repel attract	6.  The field around a magnet is symmetrical, unless disturbed. As shown in the figure above, placing a good magnetic conductor (soft iron) in the field will cause the field to redirect itself to the easier path. Likewise, the field will avoid a material that has a high opposition. If the object is removed from the field, the lines of force spring back to their original shape.

	6. (Continued) An undisturbed magnetic field is _____.
symmetrical	7. Lines of force never touch or cross. Parallel lines of force going in the same direction repel laterally; parallel lines of force going in opposite directions tend to counteract each other. Magnetic lines of force never _____ or _____ each other.
touch cross	8. Magnetism is a/an _____ (visible/invisible) force that has the ability to _____ or _____ certain materials.
invisible attract repel	9. Complete the following statements that correctly describe the properties of a magnetic field. a. Magnetic fields are _____, unless _____. b. Outside a magnet, lines of force leave the _____ _____ and enter the _____ _____. c. Unlike poles _____; like poles _____. d. Lines of force always form _____ _____. e. Lines of force never _____ or _____.

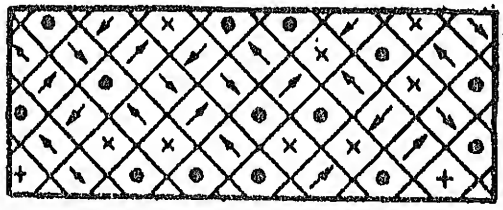
a. symmetrical disturbed b. north pole south pole c. attract repel d. closed loops e. touch cross	10. Magnets are classed as either natural or artificial. Natural magnets, such as lodestones, are materials found in nature that exhibit the properties of magnetism. Artificial magnets are man-made and much more efficient than natural magnets. An example of an artificial magnet is ALNICO (an alloy of aluminum, nickel, and cobalt). Artificial magnets are further subdivided as either permanent or temporary. Electromagnets are the commonest temporary magnets. Artificial magnets are subdivided into two types: (1) _____ and (2) _____.
permanent temporary	11. Select the statements that describe the properties of a magnetic field. ____ a. Lines of force never touch or cross. ____ b. Like poles attract; unlike poles repel. ____ c. Magnetic fields are symmetrical, unless disturbed. ____ d. Lines of force never form closed loops. ____ e. Outside a magnet, lines of force leave the south pole and enter the north pole. ____ f. Lines of force rarely touch or cross. ____ g. Magnetic fields are not symmetrical, unless disturbed. ____ h. Unlike poles attract; like poles repel. ____ i. Outside a magnet, lines of force leave the north pole and enter the south pole. ____ j. Lines of force always form closed loops.

a. c. h. i. j.	12. Select the statement that defines magnetism. a. A visible force that has the ability to attract or repel certain materials. b. An invisible force that has the ability to attract or repel certain materials. c. An invisible force that has the ability to attract or repel all materials. d. A visible force that has the ability to attract or repel all materials.
b.	13. According to the present-day theories of magnetism, magnetism originates basically in the spinning electron. Each electron spinning on its own axis is a tiny magnet having a north pole and a south pole, like the earth. Like the earth, a spinning electron has a _____ pole and a _____ pole.
north south	14. The magnetic property of any substance is determined by the balance of spinning electrons in orbit about an atom and the distance between atoms. As shown in the figure below, the effect of three electrons spinning in one direction with a like number of electrons spinning in the opposite direction results in a NONMAGNETIC ATOM.  NONMAGNETIC ATOM.

	14. (Continued) In almost all matter, the magnetism of the electron is not noticed, because this magnetism is canceled within the atoms. There is, however, a small group of elements in which this magnetism is not canceled. The magnetic metals belong to this group. Because this magnetism is not canceled, these atoms are actually small magnets. See the figure below.  MAGNETIC ATOM. Magnetic metals belong to a group of elements in which _____ is not canceled within the atom.
magnetism	15. Inside the magnetic metals, the atoms group themselves into microscopic magnetic regions called domains. IN EACH DOMAIN, ALL THE ATOMS ARE MAGNETICALLY ALIGNED IN THE SAME DIRECTION. The magnetism of the atoms adds together, and the total magnetic effect is imparted to the domain. A domain is actually a magnet with a north and a south pole. A domain is a microscopic region in which _____ _____ _____.

all the atoms are magnetically aligned in the same direction

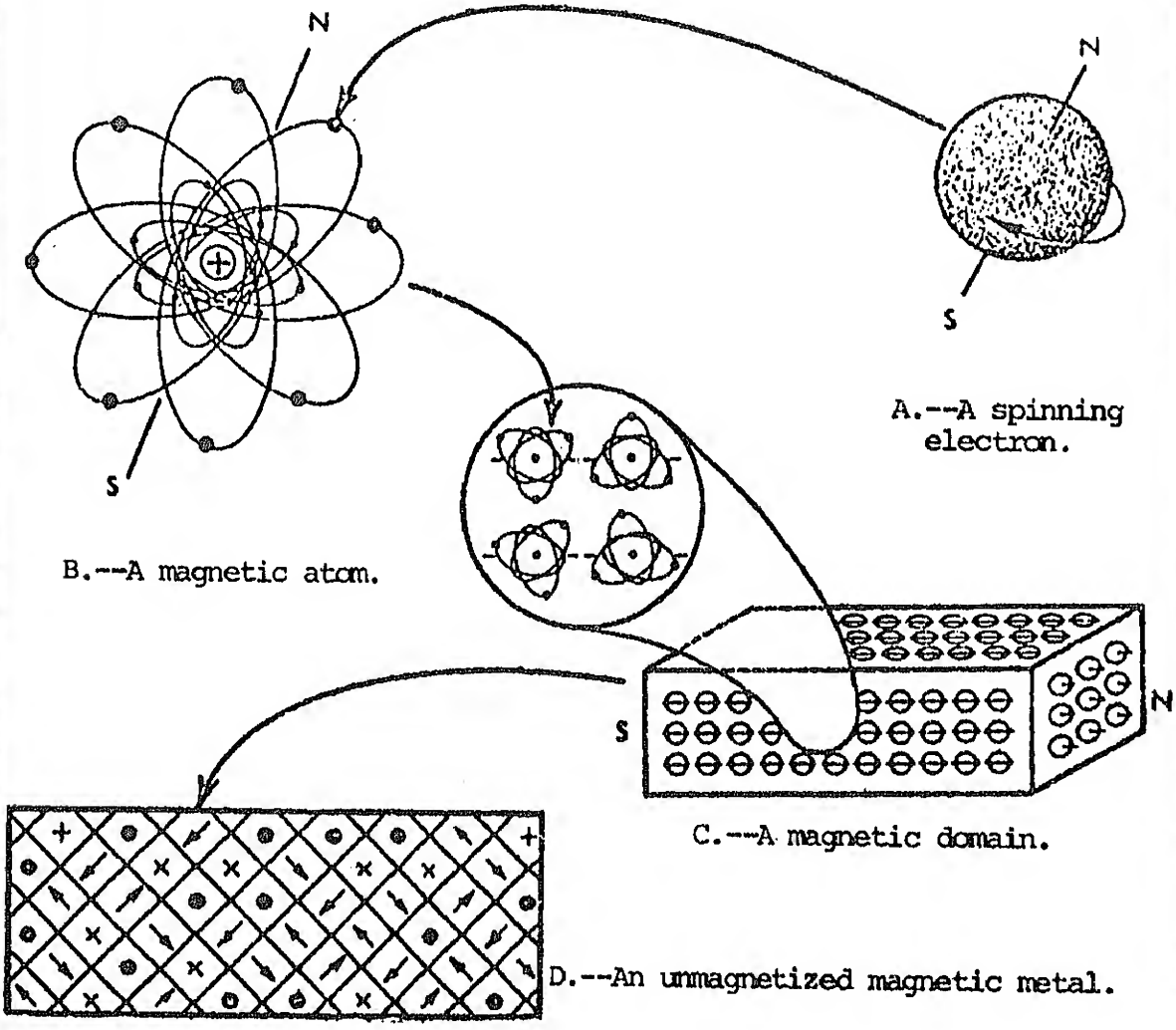
16. Although a steel bar may contain millions of microscopic domains, the bar is not necessarily a magnet. The reason for this is that the domains are not aligned; thus, the magnetic effect is canceled out within the bar itself. The resultant magnetic effect of an unmagnetized steel bar is zero. See the figure below.



An unmagnetized steel bar consists of magnetic domains that _____ aligned.
(are/are not)

are not

17. The drawings below show the sequence from the spinning electron to the unmagnetized magnetic metal.



A.--A spinning electron.

B.--A magnetic atom.

C.--A magnetic domain.

D.--An unmagnetized magnetic metal.

NOTE: In figure D, each small square represents a domain. The arrows represent the direction of magnetic alignment; The ⊙'s are arrows pointing toward the reader; the X's are arrows pointing away from the reader.

A domain is a microscopic region in which all the _____ (atoms/molecules)

are magnetically aligned in _____.

atoms the same direction	18. List two types of artificial magnets. (1) (2)
Permanent. Temporary.	19. Select the statements that describe the properties of a magnetic field. _____ a. Lines of force never touch or cross. _____ b. Outside a magnet, lines of force leave the south pole and enter the north pole. _____ c. Magnetic fields are symmetrical, unless disturbed. _____ d. Lines of force rarely touch or cross. _____ e. Outside a magnet, lines of force leave the north pole and enter the south pole. _____ f. Magnetic fields are not symmetrical, unless disturbed. _____ g. Lines of force always form closed loops. _____ h. Like poles attract; unlike poles repel. _____ i. Unlike poles attract; like poles repel. _____ j. Lines of force never form closed loops.

a.

c.

e.

g.

i.

20. According to the present-day theories of magnetism, there are three basic classifications of materials.

(1) FERROMAGNETIC materials are easily magnetized: iron, nickel, cobalt, gadolinium, and their alloys.

(2) PARAMAGNETIC materials are those that can be weakly magnetized: air, aluminum, platinum, manganese and chromium.

(3) DIAMAGNETIC materials are almost impossible to magnetize; when forced, they become weakly magnetized in the opposite direction from the magnetizing force. Copper, silver, gold, phosphorus, and antimony are examples of diamagnetic materials. Most materials are diamagnetic.

The three classifications of materials in the present-day theories of magnetism are

(1) _____,

(2) _____, and

(3) _____.

ferromagnetic paramagnetic diamagnetic	21. Flux is the name given to the lines of force that surround a magnet. The total magnetic flux, represented by the Greek letter ϕ (phi), is stated in maxwells. FLUX DENSITY (B) is the number of lines of flux per unit area. Thus, flux density is a measure relating total flux to the cross-sectional area of the flux path. Flux density (B) is stated in gauss. RELUCTANCE (R) is the total opposition offered by a material to the passage of magnetic lines of flux. PERMEANCE (P) is the total ease with which a material will pass magnetic lines of flux. RETENTIVITY is the ability of a material to retain magnetism after the magnetizing force has been removed. Retentivity determines whether a magnet is permanent or temporary. Permanent magnets have a high degree of retentivity.

	21. (Continued) Complete the following statements that define terms used in magnetism. a. Flux density (B) is the _____ of lines of _____. b. Reluctance (R) is the total _____ offered to _____. c. Permeance (P) is the total _____ with which a _____. d. Retentivity is the _____ of a material _____.
a. number flux per unit area b. opposition lines of flux c. ease material will pass lines of flux d. ability to retain magnetism	
	22. A domain is a microscopic region in which a. all the molecules are electrostatically aligned in the same direction. b. all the atoms are magnetically aligned in opposite directions. c. all the molecules are electrostatically aligned in opposite directions. d. all the atoms are magnetically aligned in the same direction.
d.	23. List two types of artificial magnets. (1) (2)

Permanent. Temporary.	24. RESIDUAL MAGNETISM is the amount of magnetism that remains in a material after the magnetizing force has been removed. MAGNETIZING FORCE (H) is the force per unit length. The terms magnetic field, magnetic field strength, and magnetic field intensity are often used for H. Magnetizing force (H) is stated in oersteds. RELUCTIVITY (ν) is the specific reluctance, or the reluctance per cubic centimeter. It is the ratio of the reluctance of a cubic centimeter of a material to the reluctance of a cubic centimeter of air. PERMEABILITY is the relative ability of a material to conduct magnetic lines of flux, or the ratio of flux produced in a material to the flux produced in air by an equal magnetizing force. The higher the specific permeability, the better the magnetic conducting quality of a material. Iron, steel, cobalt, and nickel are some of the materials that have a high permeability and provide a path of easy conduction for magnetic lines of force.

24. (Continued)

Complete the following statements that define terms used in magnetism.

a. Residual magnetism is the _____ of magnetism remaining in a _____ _____ _____.

b. Magnetizing force (H) is the _____ _____ _____.

c. Reluctivity (ν) is the reluctance per _____ _____.

d. Permeability (μ) is the _____ ability of a material to _____ _____ _____.

a. amount
material after the magnetizing force has been removed

b. force per unit length

c. cubic centimeter

d. relative
conduct lines of flux, as compared with air

	25. Flux density (B) is the number _____ _____ _____.
of lines of flux (force) per unit area	26. Reluctance (R) is the total opposition _____ _____.
offered to lines of flux	27. Permeance (P) is the total ease _____ _____ _____.
with which a material will pass lines of flux	28. Retentivity is the ability _____ _____ _____.
of a material to retain magnetism	29. Select the statement that defines a domain. a. A microscopic region in which all the atoms are magnetically aligned in the same direction. b. A microscopic region in which the magnetism of one atom neutralizes the magnetism of another atom. c. A microscopic region in which the atoms are magnetically aligned in many directions.
a.	30. Residual magnetism is the amount _____ _____ _____.

of magnetism remaining in a material after the magnetizing force has been removed

31. Match each of the terms listed in column A with the correct definition in column B.

A	B
(1) Retentivity	____ a. the total opposition to lines of flux.
(2) Permeance (P)	____ b. the ability of a substance to retain magnetism.
(3) Reluctance (R)	____ c. the number of lines of flux per unit area.
(4) Flux density (B)	____ d. the total ease with which a material will pass lines of flux.

a. (3)

b. (1)

c. (4)

d. (2)

32. Magnetizing force (H) is the force _____ _____.

per unit length

33. Reluctivity (ν) is the reluctance per _____ _____.

cubic centimeter

34. Permeability (μ) is the relative _____ _____ _____.

ability of a material to conduct lines of flux, as compared with air	35. Match each of the terms listed in column A with the correct definition in column B. A (1) Residual magnetism (2) Magnetizing force (H) (3) Reluctivity (ν) (4) Permeability (μ) B _____ a. the reluctance per cubic centimeter. _____ b. the relative ability of a material to conduct lines of flux, as compared with air. _____ c. the amount of magnetism remaining in a material after the magnetizing force has been removed. _____ d. the force per unit length.
a. (3) b. (4) c. (1) d. (2)	36. State the definition of residual magnetism.
The amount of magnetism remaining in a material after the magnetizing force has been removed.	37. State the definition of magnetizing force (H).
orce per ength.	38. State the definition of reluctivity (ν).

The reluctance per cubic centimeter.	39. Select the correct definition for permeability (μ). a. The relative ability of a material to conduct lines of force, as compared with air. b. The relative amount of magnetism remaining in a material after the magnetizing force has been removed. c. The absolute number of lines of force of a material, as compared with air.
a.	40. Reluctivity (ν) is the reluctance per _____ _____.
cubic centimeter	You have completed this program. Review the objectives on page i. If you do not understand an objective, turn to the frame/s indicated by the number/s in parentheses.

REFERENCES:

1. Basic Electricity. NAVPERS 10086-A, 1960. Washington, D. C.: Government Printing Office. Chapter 1, pages 7-14 and chapter 7, pages 120-129, 200-210.

2. Grob, Bernard. Basic Electronics. New York: McGraw-Hill Book Company, Inc., 1965. Chapter 11, pages 198-210, and chapter 12, pages 221-229.

3. Slurzberg, Morris, and William Osterheld. Essentials of Electricity-Electronics. McGraw-Hill Book Company, Inc. Third Edition. Chapter 5, pages 143-160.

REVIEW TEST

P-IV-1R--Magnetic Theory: Magnetism

1. Select the statement that defines magnetism.

   a. An invisible force that has the ability to attract or repel all materials.

   b. A visible force that can be measured.

   c. An invisible force that has the ability to attract or repel certain materials.

   d. A visible force that exists in all materials.

2. Select the statements that describe the properties of a magnetic field. (Place an X by your choice.)

   ___ a. Magnetic fields are symmetrical, unless disturbed.

   ___ b. Outside a magnet, lines of force leave the south pole and enter the north pole.

   ___ c. Magnetic fields are not symmetrical, unless disturbed.

   ___ d. Outside a magnet, lines of force leave the north pole and enter the south pole.

   ___ e. Unlike poles attract; like poles repel.

   ___ f. Lines of force always form closed loops.

   ___ g. Like poles attract; unlike poles repel.

   ___ h. Lines of force rarely touch or cross.

   ___ i. Lines of force never form closed loops.

   ___ j. Lines of force never touch or cross.

3. List two types of artificial magnets.

   (1)

   (2)

4. Select the statement that defines a domain.

   a. A microscopic region in which the magnetism of one atom neutralizes the magnetism of another atom.

   b. A domain is a microscopic magnetic region in which all the atoms are magnetically aligned in the same direction.

   c. A microscopic region in which the atoms are magnetically aligned in many directions.

5. Match each of the terms listed in column A with the correct definition in column B.

A	B
(1) Permeance	_____ a. the ability of a substance to retain magnetism.
(2) Flux density (B)	_____ b. the number of lines of flux per unit area.
(3) Retentivity	_____ c. the total opposition to lines of flux.
(4) Reluctance (R)	_____ d. the total ease with which a material will pass lines of flux.

6. State the definition of residual magnetism.

7. State the definition for magnetizing force (H).

8. State the definition for reluctivity (ν).

9. Select the correct definition for permeability (μ).

   a. The relative ability of a material to conduct lines of force, as compared with air.

   b. The relative amount of magnetism remaining in a material after the magnetizing force has been removed.

   c. The absolute number of lines of force of a material, as compared with air.

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NAVAL LEADERSHIP

GENERAL ORDER
NO. 21

NAVY DEPARTMENT
WASHINGTON, D. C., 1 May 1963

LEADERSHIP IN THE UNITED STATES NAVY AND MARINE CORPS

Part I—Discussion

The United States Navy-Marine Corps records of victorious achievements on land, at sea, and in the air in peace and war have won for these services an honored position in our great nation. This heritage was passed on to us by our leaders, both officer and enlisted, whose outstanding examples of courage, integrity and devotion to duty are historically significant. They accomplished their missions successfully by high caliber leadership and personal example. The strength of our nation and of our services depends upon courageous, highly motivated and responsible individuals.

Part II—Objective

The objective of this general order is to achieve an ever-improving state of combat readiness by:

a. Emphasizing that successful leadership at all levels is based on personal example and moral responsibility.

b. Insuring that every man and woman are themselves examples of military ideals.

c. Requiring personal attention to and supervision of subordinates.

Part III—Action

1. The Chief of Naval Operations and the Commandant of the Marine Corps shall be directly responsible for maintaining optimum leadership standards. The Under Secretary of the Navy shall be responsible for the proper implementation of this order.

2. Fleet, Force, Type and Administrative commanders shall review each command's leadership posture as an integral part of military inspections and shall include their evaluation in inspection reports.

3. Every command and every major office and bureau of the Navy Department shall, on a continuing basis, review its leadership standards; each shall take effective measures to improve them and shall develop an awareness of the need for good leadership by providing programs for instruction in leadership principles and practices.

4. All persons in responsible positions, military and civilian, shall require that their subordinates discharge their duties in accordance with traditional concepts of Navy and Marine Corps standards, paying particular attention to:

a. Moral responsibility.
(Article 0702A, Navy Regulations—Paragraph 5390, Marine Corps Manual.)

b. Personal example of behavior and performance.
(Article 1210, Navy Regulations—Paragraph 5390, Marine Corps Manual.)

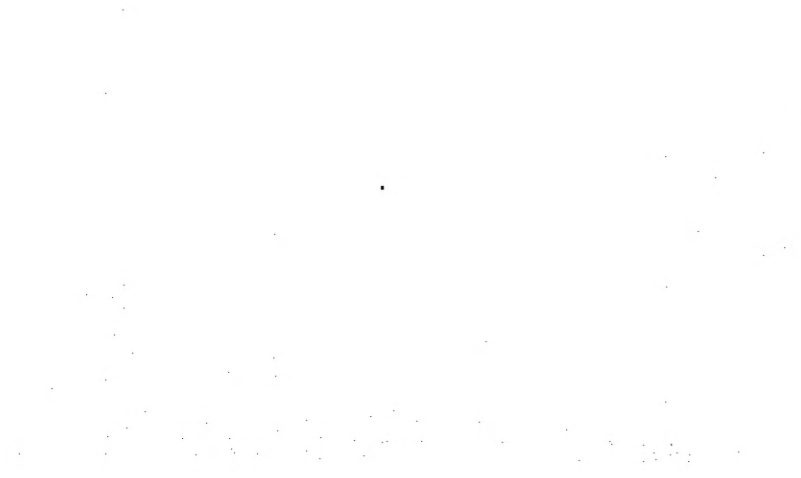
c. Established standards for personnel development.
(Article 0710, Navy Regulations—Paragraph 1500, Marine Corps Manual.)

d. Integration of principles and practices of leadership into everyday routine.
(Article 0709, Navy Regulations—Paragraph 5390, Marine Corps Manual.)

e. Effective organization and administration.
(Article 0704, Navy Regulations—Paragraph 3000, Marine Corps Manual.)

FRED KORTH
Secretary of the Navy

NAVPERS 15202



THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.